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AD HOC UAV LTE NETWORKS FOR CRITICAL COMMUNICATIONS

SETTAPONG MALISUWAN & WASSANA KAEWPHANUEKRUNGSI

National Broadcasting and Telecommunications Commission, Thailand

ABSTRACT

Small-scale unmanned aerial vehicles (UAVs) have been used for military and public-safety operations. Today's military and disaster-response personnel have become accustomed to smartphones connected to commercial communications networks in their personal lives. Specialized ad-hoc networks of unmanned aerial vehicles have been playing increasingly important roles in applications for military and public safety. Given that reliable communication is critical in a variety of aerospace and defense missions, applications, and environments, high-level military and disaster-recovery officials are looking to upgrade ineffective communications infrastructures with modern telecommunication technologies, including Long-Term Evolution (LTE) and Long-Term Evolution Advance (LTE-A) technology. The objective of this paper is to propose a concept of the mission-critical UAVs ad-hoc LTE networks. The proposed concept aims to present the LTE standards-based architecture for powerful military and public-safety tools, enabling UAVs rapid response to threats and lending to mission successes and lives saved.

KEYWORDS: Ad Hoc Network, UAV, LTE, Military, Public Safety

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Original Article

INTRODUCTION

Disasters and threats can arise every time and everywhere. Therefore, the competency in constructing public safety communications networks that are fast and efficient is very vital and becomes the key factor that promotes success in public calamity or disaster mitigation and defense missions. The top priority is that the personnel responsible for preventing and mitigating disasters must be able to apply their communication competencies in a full range of situations, such as restoring damaged infrastructures in both urban and rural areas under limitations or setting up new infrastructures in the areas that have never had Internet connectivity before. For example, the security has to exchange news and information on incidents which may occur during times of crisis as well as use ground robots and unmanned aerial vehicles (UAVs) to carry out missions in forbidden or hard-to-reach areas, share out or exchange information with various groups of stakeholders to facilitate risk assessment, decision making, and mission accomplishment, use robots for emergency-response missions, be capable of installing communication devices to enable data transmission among groups of disaster-response personnel in remote areas or intercommunication between robots in hard-to-access areas.

Nowadays, advanced communications through utilization of small-scale UAVs that can function as communication repeaters for handheld radios will promote further expansion of the line of sight (LOS): possibly wider than 150 nautical miles for handheld radios and small enough for being installed into the payload bay [1]. Small-scale unmanned aerial vehicles (UAVs) have caught great attention due to its capability for transferring and storing tremendous amounts of data. They use the 4G LTE technology to transmit necessary data between the base station controller and UAVs.

By utilizing an ad-hoc LTE network, which is all-IP and standards-based, militaries gain access to a large pool of technology vendors—translating to greater parts availability, competitive pricing, and interoperability [2]. UAVs will create an ad-hoc network which it then uses to communicate and act as a relay-mechanism.

The UAVs ad-hoc LTE network is [3] a method of sending data to far-off receivers, using a single or multiple relays 1 as shown in Figure 4. Generally, the UAV ah-hoc LTE network is of the multiple-hop wireless type where each node functions as a cell phone signal receiver, similar to the router used in forwarding data to another nearby area. Therefore, all nodes in the network are connected to each other with no need for installing any infrastructure such as a satellite or a base station composed of several antennas. This will prove that the UAVs ad-hoc LTE network has become the technology that is efficient and worth investing in. Furthermore, each node of the UAVs ad-hoc LTE network is able to move freely toward or away from its nearby nodes, resulting in connections being formed or broken. Therefore, it is necessary that the UAVs ad-hoc LTE network require specific means of communications which enable it to automatically deal with problems at hand. Sometimes, rapid changes in multi-hop structures are the results of UAVs' movements. The routing protocol exemplifies the process of exploring communication routes in the network located between nodes or relays, which will enable various messages and data to be successfully transferred to target receivers.

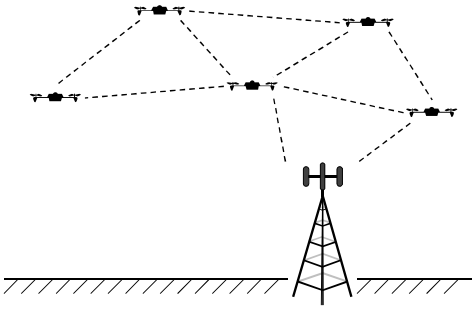

Figure 1: UAVs AD HOC Network

Reliable communications are very vital for various activities in relation to aeronautics and aerospace, the Ministry of Defense, advanced military affairs, and other agencies responsible for disaster prevention and mitigation, etc. These aforementioned sectors will have to improve their outdated communication systems and inefficient infrastructures through application of modern infrastructures and commercially-worthwhile technologies such as the LTE technology.

Effective communications are essential, making LTE is a must-have technology on which military and disaster-recovery personnel rely to increase mission effectiveness and save lives [5]. The paper organizes the content as follows. Section II presents UAVs Ad-hoc LTE Network. Section III introduces LTE for UAVs platform. The last section is the conclusion.

UAVS AD HOC LTE NETWORK

The tryout of UAV Air-to-Ground links according to the study of [6] (the statistical model of air-to-ground channels operated at frequencies from 200 MHz to 5 GHz in an urban environment) was conducted by using UAVs for other missions other than military affairs, especially for public networks where UAVs will support the needs of security agencies in good time. The advantages of Air-to-Ground-links application on the currently-used mobile phone networks are that they provide massive service coverage, are able to use the network which has already existed, have low investment costs, and can facilitate communications among networks.

The liberal use of UAVs Air-to-Air links along with other devices results in the public wireless network technology becoming the communication technology which is more possibly applicable for UAVs. In case there is an emergency event regarding the public network due to calamities or natural disasters that completely or partially disrupts network utilization, either mobile ad-hoc WLAN infrastructures or base stations are considered one of the solutions that the emergency response agency can adopt. The Air-to-Air/ Air-to-Ground UAVs ad-hoc network is illustrated in Figure 2.

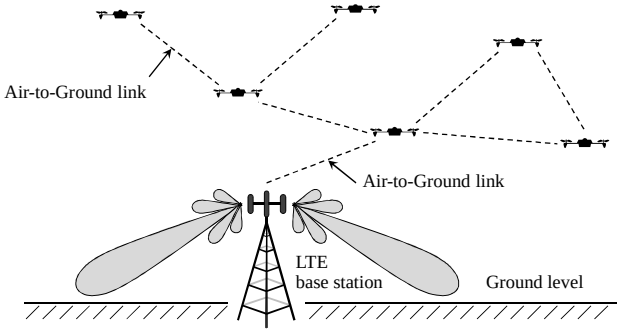

Figure 2: Air-to-Air/Air-to-Ground UAVs AD HOC Network

The UAV ad-hoc mesh network allows coverage of a large area. Since it might happen that not all UAVs have a connection to the base station on their own due to loss of Air-to-Ground link, additional Air-to-Air links are used for routing those data to a neighboring relay UAV, which works as gateway to a ground station. For the implementation of Air-to-Air links different communication technologies and frequencies are available. Routing protocols for WLAN are already available for embedded and low-weight devices which can easily be mounted to small-scale UAVs.

Since UAVs are very flexible and considered low-cost communication devices, it is possible that they can be used for ad-hoc networks. However, there are some limitations in execution proceedings because the networks currently available for service provision may not be suitable for UAVs owing to the rapid changes in UAV ad-hoc networks of which the architectures are not flexible enough to bring about quality services. Therefore, the cross-layering technique is applied in the Air-to-Air link design to facilitate the interaction between layers and allow us to tune layer parameters so that the overall performance is sufficient [7].

LTE TECHNOLOGY FOR UNMANNED AERIAL VEHICLES PLATFORM

The LTE Technology Release 10 or LTE Advanced (LTE-A) has improved the capability for utilizing UAVs in the restoration or expansion of areas in order to provide faster public safety services.

- **Relay Node (RN)**

The working boundary of relay nodes is within indoor service areas or edges of cell sites so as to expand additional service areas called repeaters. The relay node can be quickly installed and used with no wiring needed, but the connection of relay nodes will rely on the capacity of partial cell sites which currently available for mobile phone service provision. Though relay nodes are able to tradeoff the capacity between each other, this does not affect the traffic route to be in the main network again [8].

The advantage of relay nodes is that they can be quickly installed and utilized. In case of disasters, the damaged ground systems or networks have to be restored. The utilization of UAVs during a brief period can be carried out in a very short time, enabling the base station to provide communication services as usual. Moreover, it is considered the best practical

solution to public safety related problems for mobile phone service providers because it does not require additional radio spectrum.

Apart from expanding areas of service provision for a temporary period, the relay node can be used in UAVs by enabling them to connect handheld radios with the nearest base station, but only within the limited altitude at 100 meters above the ground.

For the remote utilization, it is more complex and requires further advance planning, whereas UAVs can carry out public safety duties automatically. If the complexity of UAV utilization is increased through using a full range of LTE base stations, there is no need for any other alternative technologies to be adopted and for users to be provided with training [8].

Regarding the public safety community, telecommunications infrastructure constructors and mobile phone network service providers must cooperate with state agencies and regulatory sectors to impose basic regulations on LTE-UAV utilization. Further commercial development on the deployment models for LTE-UAV will remain a difficult work until the governments and regulators provide clear rules and regulations.

Aerial-eNB

The mobile phone networks for public safety and first responders in emergency disaster-affected areas, to coordinate with rescue units and emergency medical services, will be easily installed for utilization in affected areas through the use of directional antenna in Aerial-eNB gained within macrocells. In developing the design, the architecture of mobile phone networks is used on the basis of the hybrid aerial-terrestrial approach as shown in Figure 3. It is obvious that the connections are flexible, able to be applied in different situations, depend on weather conditions and application of compositions in the LTE network [9]. The hybrid aerial-terrestrial approach in our design is adopted from the study in [10] which is the ad-hoc network of 4G LTE-WiFi multimode base stations for UAV platform.

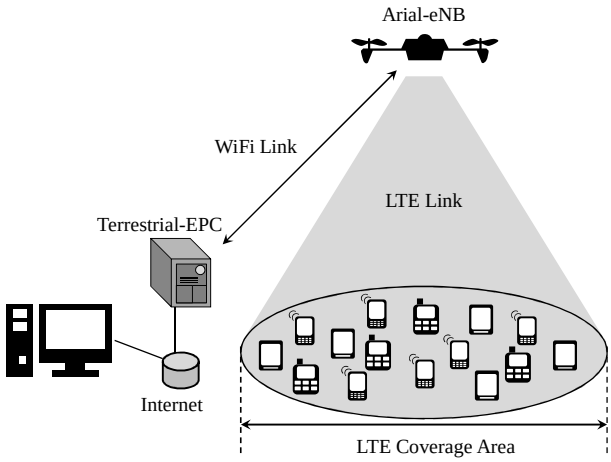

Figure 3: Hybrid Aerial-Terrestrial LTE-WiFi Approach

AP Mode: Two Hops

The research in [11] proposed a multi-antenna extension to 802.11a to achieve the height and orientation differences in aerial networks. The proposed communication system can provide high UDP throughput over single-hop links. The AP mode with two hops is shown in Figure 4.

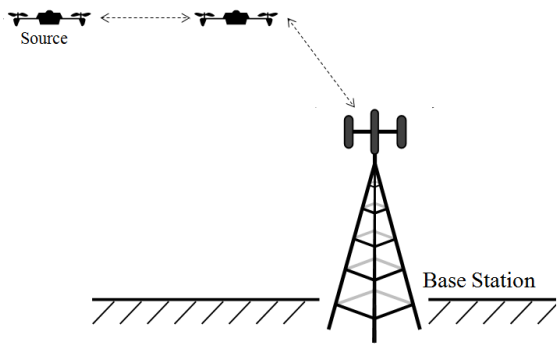

Figure 4: AP Mode: Two Hops [11]

CONCLUSIONS

The objective of this paper is to present UAVs Ad hoc Networks as applied to public-safety and military in critical communications missions. The paper describes the architecture of UAVs Ad hoc LTE Network and proposes LTE for UAVs platform. In this research, the paper proposes a hybrid aerial-terrestrial LTE-WiFi approach applied it with AP mode 2 hops network. For future work, we will simulate these network environments in several conditions.

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